

rentiam non satis attendisse videtur Doctissimus *Jurinius*, à vero multum aberrasse mihi videtur. Si igitur sepositâ suâ, de Vasorum ictu, hypothesi, & vi pressuræ, quâ Natura utitur, pro Principio adhibitâ, alia Theoremata de Cordis & Sanguinis motu & viribus, eleganter suâ demonstrationis methodo, construere dignabitur, sese dignum, mihi certe gratum, nec eruditis inutile præstiterit. Tu, qui Rei Medicæ principatum tenes, Vir Amplissime, dissentientium disputationes tuâ prudentiâ ita moderari digneris, ne Indoctis ludibrio, sed ut Doctis emolumento esse possint. Dabam *Norhamptonia* 23. die *Junii* 1719.

III. *An account of some Experiments relating to the Specifick Gravity of Human Blood.* By James Jurin, M. D. and F. R. S.

IT is well known from the Observations of Mr. *Leeuwenhoek* and others, that Human Blood consists of red globular Particles, swimming in a pellucid *Lympha*, or *Serum*. Which two different Substances, tho' of unequal Specifick Gravities, yet so long as they continue to circulate in the Veins and Arteries, are prevented from separating by their Motion and Warmth. But when the Blood comes to stagnate and cool in a Porringer, the globular Particles uniting together by their attractive Power, and sinking by their Weight, which is greater than that of the *Serum*, form the *Coagulum*, or *Crassamentum*, at the bottom of the Porringer, the *Serum* swimming above it.

Things always happen in this manner, when the *Crassamentum* is at liberty to subside: but it often falls out, that, either by its adhesion to the sides of the Vessel, or by the bubbles of Air, which the Blood

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gathers

gathers upon falling into the Perringer, and which stick to it's Surface, the *Craffamentum* is kept from sinking, and seems to float upon the top of the *Serum*.

These Accidents seem to have given the first occasion to that Opinion, which, I think, has been generally entertain'd by those who have writ upon this Subject, namely, that the globular part of the Blood is specifically lighter than the *Serum*, in which it swims.

But that which has so fully establish'd this persuasion, is the Authority of the late excellent Mr. *Boyle*, who, among the many valuable and curious Experiments he has given us in his Natural History of Human Blood, has left the following ones upon this Subject.

The specifick Gravity of *Serum* of Human Blood was found by weighing a piece of Sealing Wax first in *Serum*, and afterwards in Water, to be to the specifick Gravity of Water, as 1024 to 1000.

In a second Experiment, which for greater accuracy was made with an Instrument contriv'd on purpose, the specifick Gravity of *Serum* was found to be to that of Water, as 1194, to 1000.

In a third Experiment made by the same Instrument, and with *Serum* from the Blood of another Person, it's specifick Gravity appear'd to be 1186.

The Medium between these two last Experiments is 1190, which has since been universally receiv'd for the specifick Gravity of *Serum* of Human Blood, the first Experiment being declar'd by Mr. *Boyle* himself to be less exactly made than the other.

The specifick Gravity of Human Blood was found by Mr. *Boyle*, to be to that of Water, as 1040 to 1000; though on account of difficulties by him mention'd, he was far from being satisfy'd with this Experiment, and recommended the thing to farther tryals.

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These Experiments however having hitherto past uncontroverted, and it appearing from them, that the specifick Gravity of *Serum* was greater than that of Blood in the proportion of 1190 to 1040. or of 8 to 7 nearly; it was a necessary consequence of this, that the Blood Globules were specifically lighter than the *Serum*, and that in a very great degree, considering the small proportion. that the bulk of the *Craffamentum* was found to bear to that of the *Serum*, from other Experiments.

From this it was not improbably conjectured, that these Globules were thin Vesicles fill'd with an Aereal substance: and this Opinion seem'd to receive a great confirmation, upon it's being observ'd, in viewing the Circulation by a Microscope, that a Blood Globule, in passing through a very narrow Vessel, would change its shape from a Globular to an Oval Form, and would recover it's former Figure, as soon as it was got thro' the narrow Passage; which appearance seem'd to be naturally accounted for from the Elasticity of the included *Aura*.

Upon this conjecture have been built a great many Solutions of the Phænomena observable in the Animal Oeconomy, and the disorders of it; particularly a late ingenious account of Muscular Motion. It is not my business at present to examine any of these, nor is it my design to cast any reflection upon their Authors, who were led into this mistake by the natural consequence of a matter of Fact, for the truth of which they had so great an Authority, as that of the excellent Person above-mentioned. But I hope, I shall easily be pardon'd for enquiring into the soundness of the Foundation, when the Superstructure erected thereupon is so considerable; and the following Experiments, however trivial in themselves, will not appear unworthy the

the consideration of the *Royal Society*, if it be found, that they may prevent us from running into Errors of the greatest consequence.

Exp. I. I have several times cut off a small part of the *Craffamentum*, when by its adhesion to the sides of the Porringer it has seem'd to swim upon the Surface of the *Serum*, and have put it into another Vessel fill'd with *Serum*: upon which it has immediately sunk to the Bottom.

Exp. II. When the *Coagulum* has been buoy'd up in the *Serum* by the bubbles of Air adhering to its Surface, I have separated a small part of it, where those Bubbles have been thickest, and put it into a Glass of *Serum*, in which it has swom, as before. Then setting the Glass upon the Air-Pump, those Bubbles burst after one another, as the Receiver was exhausting, and the Air being again let into the Receiver, the lump of *Craffamentum* sunk to the bottom of the Glass.

Exp. III. I have often placed a drop of *Serum* upon a clean Glass before a Microscope, in which I had dissolv'd a very small quantity of Blood, and observ'd, that when the Glass was held in a perpendicular Posture, the Blood-Globules subsided to the bottom of the Drop; and inverting the Glass, the Globules again descended thro' the *Serum* to the Bottom. I had the same success with a small quantity of *Serum* and Blood in a Capillary Tube. And the same thing has been long since observ'd by the famous Mr. *Leeuwenhoek*.

These Experiments undeniably demonstrate, that the *Craffamentum*, or globular part of the Blood, is specifically heavier than the *Serum*; and consequently it is by no means probable, that the Blood Globules are Vesicles fill'd with Air, or any other Fluid lighter than *Serum*. And that they are not fill'd with any sort of

Elastick Fluid, will appear from the following Experiment.

Exp. IV. In a small quantity of *Serum* of Human Blood, I dissolv'd so much Blood, as that the Globules might not lye too thick together, to hinder their being seen distinctly. Then having lodged a small drop of this Liquor on the inside of a thin Glass Tube, I fitted the Tube on to the Air-Pump, and placed a Microscope by it, so that I could see the Blood-Globules through the Tube. This being done, I caus'd the Tube to be exhausted, keeping my Eye upon the Globules all the time, in order to observe whether they dilated themselves, as the Air was withdrawn; but could not perceive the least alteration, they appearing exactly of the same bigness in the *Vacuum*, as they had done before. Whereas if they had been fill'd with an Elastick Fluid, they would either have burst, or have been dilated to at least 70 or 80 times their former Magnitude. The Stop-cock being afterwards turn'd, and the Air suffer'd to re-enter the Tube, the Blood-Globules still retain'd the same bigness, as in *Vacuo*.

To this it will perhaps be objected, that a learned Member of this Society, in a Book lately publish'd, has asserted the direct contrary to what I here affirm, and has assur'd us, that the Blood-Globules in an exhausted Receiver, instantly swell, and dilate themselves so, as to become incredibly large. But as that Gentleman does not tell us, upon what Experiment this assertion is grounded, it may not be unreasonable to suppose, that he was misled by the common Hypothesis, which he there maintains, of the Blood-Globules being fill'd with Air, and by what he has heard or seen of the bubbles of Air, which arise from Blood in the Air Pump in the same manner as from other Liquors, and which not easily breaking out from so viscid a Fluid, occasion
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the appearance he mentions. However this may be to prevent any dispute, and avoid the coming to *Utri creditis, Quirites?* I shall offer a Testimony, that every body will be satisfy'd with, namely that of the learned and ingenious Mr. *Machin*, Professor of *Astronomy* in *Gresham Colledge*, and one of our Secretaries, who having honour'd me with his Company at a repetition of this Experiment, in order to be witness to the Event, was fully satisfied upon repeated tryals, that there was no perceivable difference between the Magnitude of the Blood Globules in the Air, and in *Vacuo*. Upon this occasion the two first Experiments were likewise repeated in his presence, with the same Success, as above related.

Though what has been already said is a sufficient proof of the Opinion above-mention'd, yet however to prevent the Objections, which may arise for want of Experiments made in the same manner with Mr. *Boyle's*, as well as for the satisfaction of the Curious, who may be desirous to know the true Specifick Gravities of *Serum* and Blood, I shall proceed to demonstrate the same thing by Hydrostatical Experiments.

Exp. V. Novemb. 13. 1713. Having suffer'd a quantity of my own Blood to stand about 24 Hours in the Porringer, and then drawing off the *Serum* carefully with a small *Siphon* into a convenient Glass, I found by the Hydrostatical Balance it's Specifick Gravity to be to that of Water, as 1029,8 to 1000.

Exp. VI. Feb. 21. 1716-7. I examin'd the *Serum* from the Blood of another Person in the same manner and found it's Specifick Gravity to be 1028,6.

Exp. VII. VIII. and IX. April 8th, 1717. I obtain'd three several quantities of *Serum* from the Blood of different Persons. The first of these was of a deep

Colour, inclining something to red, and a little Turbid. It's Specifick Gravity was 1029, 7.

The second was likewise a little Turbid, and of a pale whitish Colour. The Specifick Gravity of this was 1030, 2.

The third quantity of *Serum* was perfectly clear, and of the colour of Canary. It's Specifick Gravity was found to be 1030.

Though these five several Experiments were all carefully made, and with a Balance whose accuracy I was well assur'd of, yet for farther Evidence, I thought it proper to make that which follows, after another manner.

Exp. X. Jan. 15th. 1718-9. I drew off all the *Serum* from five or six several Porringers, containing the Blood of different Persons. This I found to be a little tinged with Blood, which was occasion'd by my being oblig'd to draw it off pretty near to the bottom of the Porringers, in order to obtain a quantity sufficient for my purpose. For this reason I suffer'd it to stand about two Days, in which time the Globular part of the Blood was entirely precipitated to the Bottom, and the *Serum* was become perfectly fine and transparent. I then drew it off with a *Siphon* into a Glass Vial with a narrow Neck, which I fill'd to a certain mark made in the Neck for that purpose. This done, I plac'd my Vial in a nice pair of Scales, in which I had a counterpoise for the weight of the Vial, and found that quantity of *Serum* to weigh 2284½ Grains.

Then pouring out the *Serum*, I fill'd the Vial with common Water to the same mark, and found the weight of the Water to be 2219 Grains.

From which it follows, that the Specifick Gravity of this *Serum* was 1029, 4.

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Exp. XI. July 14. 1719. I procur'd a quantity of Blood taken from the temporal Artery, from which I drew off the *Serum* the next Day, and weighing it in the same manner found it's Specifick Gravity to be 1028, 8.

These Experiments agree so nearly together, that the little difference between them may very well be attributed to that which is between the *Serum* of different Persons; or to the variations occasion'd by heat and cold in the several Seasons of the Year, in which they were made. So that from them we may safely determine the Specifick Gravity of *Serum* of Human Blood at a Medium to be 1029, 5, or in a round number 1030. From which the greatest Variation in any of these Experiments is little more than one in 1000; whereas the difference between Mr. Boyle's Experiments and mine amounts to 160 in 1000.

Exp. XII. April 6. 1717. In order to find the Specifick Gravity of Human Blood, which, by reason of it's tenacity, and sudden alterations upon standing, cannot be determin'd by the Hydrostatical Balance; I took a narrow-neck'd Vial, and fill'd it to a Mark, with Blood pour'd immediately out of the Porringer, as soon as the Person was blooded. This I weigh'd, as I had done the *Serum* before, and found it's Specifick Gravity to be 1051.

Exp. XIII. Aug. 5th. 1717. Having fill'd the same Vial with the Blood of another Person, running immediately out of the Vein through a Funnel, it's Specifick Gravity was determin'd at 1053.

Suffering this to stand till it was cold, I found the Blood was sunk a small matter below the Mark in the neck of the Vial. This being fill'd up with the Water, which in so small a quantity could make no sensible

ble difference from Blood, I found the Specifick Gravity of cold Blood to be 1055.

Exp. XIV. Aug. 6th. 1718. The last Experiment being repeated in the same manner as the Year before, the Specifick Gravity of cold Blood was again found to 1055.

Exp. XV. July 14th. 1719. The Arterial Blood, from which the *Serum* was afterwards drawn off for the 11th Experiment, being weigh'd in the same manner, it's Specifick Gravity was 1052, 5.

As this Arterial Blood and it's *Serum*, differ no more in Specifick Gravity from Venal Blood and *Serum*, than the several Portions of these do from one another, it's plain, that the difference in this respect between Arterial and Venal Blood is wholly inconsiderable. The Animal Oeconomy indeed teaches us, that the *Serous* Liquor is perpetually drawing off from the Arterial Blood by the several Secretions, but as the quantity separated in one Circulation is very small, the Blood must arrive in the Veins nearly of the same density, as when it runs through the Arteries.

In the 13th Experiment we observ'd, that the Blood alter'd it's Specifick Gravity upon cooling from 1053 to 1055; from which we may infer, that if the Blood made use of in the 12th Experiment had been suffered to stand till it was cold, it's Specifick Gravity would have been 1053; wherefore, taking a Medium between the four last Experiments, we may allow the Specifick Gravity of cold Human Blood to be 1054.

The difference of 14 Parts in a 1000, between this and the Specifick Gravity determined by Mr. *Boyle*, is easily accounted for, if we consider, that that Gentleman did not make use of a Vessel with a narrow Neck, as plainly appears from the circumstances mentioned

tioned in his Experiment; and consequently a small error in the height of the Liquor would make a considerable alteration in the Specifick Gravity.

Since therefore the Specifick Gravity of Human Blood is 1054, and that of its *Serum* 1030, it is plain, that Blood is heavier than *Serum* by about one part in 43. From which it manifestly follows, that the Globular part of the Blood is specifically heavier than the *Serum*, since the Globular part being separated from the Blood leaves the remainder, or the *Serum*, specifically lighter than the intire Mass.

But in order to determine the exact Specifick Gravity of the Blood Globules, it is first necessary to know the Proportion, which the whole quantity of the *Crassamentum* contained in Blood bears to the *Serum*. To this end Mr. Boyle has given us two several Observations of the weights of the *Crassamentum* and *Serum*, after they have separated one from another in the Porringer. But besides the difficulty of making this Experiment with any tolerable exactness, it is to be consider'd, that there is a great deal of *Serum* contain'd in the interstices of the Globules, that compose the *Crassamentum*.

This difficulty however is in some measure answer'd by two other Experiments, which Mr. Boyle made for this purpose, after the following manner. He put a quantity of the *Crassamentum* already separated from the *Serum*, into an Alembick, and distill'd off the remaining *Serum* to dryness, but without drawing off the Oil, or Volatile Salt; after which he weigh'd the distill'd Liquor, and the dry Mass left behind.

By comparing these Experiments with the two former, it will be found that the entire weight of *Serum* contain'd in Blood is nearly $\frac{2}{3}$ of the whole, and consequently

consequently the weight of the dry'd *Craffamentum* is only two fifteenths of the Blood.

But for farther satisfaction, an Analysis was made at my desire with a large quantity of Blood, amounting to four Pounds fourteen Ounces, by that ingenious and skilfull Chymist, Mr. *John Brown*.

From this was obtain'd, with a very gentle heat, two Pounds, fourteen Ounces, and six Drachms of a Phlegmatick Liquor, that had scarce any thing of the foetid Scent, which is usual in the distillation of Animal Substances; and its Specifick Gravity was nearly the same with that of common Water, being but 1000,8. This being mixt with a strong solution of Alum, scarce afforded any *Coagulum*; but exhibited a considerable one upon mixture with a solution of *Roman Vitriol*.

The distillation being continued with the same Heat, we had seven Ounces more of Phlegm considerably impregnated with Volatile Salt, as was manifest from the Smell. The Specifick Gravity of this was 1007, and having mix'd it with *Tinctura Martis optima*, Solution of Alum, and of *Roman Vitriol*, a large *Coagulum* was precipitated. In distilling these there was lost by Evaporation, two Ounces and two Drachms.

The third portion of Liquor, being rais'd with a stronger Fire, amounted to seven Ounces six Drachms: This was reddish, and turbid, and so strongly charg'd with Volatile Salts, that it might very well deserve the name of Spirit. Its Specifick Gravity was 1080,1.

Besides these we had seven Drachms of Volatile Salt, an ounce of Oil, and eight Ounces four Drachms of *Caput Mortuum*, which still retain'd some small remainder of the Oil, as was manifest from its taking Fire at the flame of a Candle. In this latter part of the Operation was lost three Ounces, seven Drachms.

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Upon making due allowance for the difference between the Specifick Gravities of the three first Portions of Liquor and that of *Serum*, as likewise for what was lost in the two several parts of the Operation, which we may reasonably conclude to have been of a Specifick Gravity nearly the same with that of the Liquor drawn off, it will be found, that the quantity of *Serum* contain'd in this Mass of Blood was about $\frac{12}{17}$ of the whole Weight, and consequently that the quantity of *Craſſamentum* was $\frac{5}{17}$ of the same Weight.

If we calculate therefore upon this Supposition, that the weight of the Globular part of the Blood is $\frac{12}{17}$ of the whole, we shall find the Specifick Gravity of a Blood Globule to be to that of Water as 1277 to 1000.

If we follow the proportion of $\frac{12}{17}$, which results from Mr. Boyle's Experiments, the Specifick Gravity of a Blood Globule will be 1242.

But this computation is in all appearance a great deal too large; for we cannot be assur'd, that our whole quantity of aqueous Liquor was rais'd from the *Serum* of the Blood. On the contrary it is more than probable, that a considerable part of it was afforded by the Blood Globules themselves, especially in the latter part of the Operation, when their texture must of necessity have been broken and dissolv'd by the strong Fire that was made use of. To prove this, we need only consider the condition of the dry'd *Craſſamentum*, after the Phlegm is drawn off, that being now a hard and brittle substance: whereas the Globules in their natural State are soft and yielding. For which reasons it may perhaps be more satisfactory, if we attempt to find the quantity of the Globular part of the Blood after another manner.

It appears therefore from Mr. Boyle's Observations, that the quantity of *Serum*, which may be pour'd off

From the *Crassamentum*, is about one half of the whole Mass. The remaining *Crassamentum* consists of the Blood Globules, and a quantity of *Serum* filling up the Interstices between them; which, if the Globules keep their Spherical Form, may easily be found by the principles of common Geometry, to be nearly one half of the bulk of the *Crassamentum*: but if the Globules by their pressure against one another change their Figure, the quantity of *Serum* will be something less.

If this quantity of *Serum* lying between the Blood Globules be added to that pour'd off, it appears, that the *Serum* contain'd in Blood is about $\frac{3}{4}$ of the whole bulk, and consequently that the Blood Globules make about $\frac{1}{4}$ of the whole. From which we shall find the Specifick Gravity of the Blood Globules to be to that of Water as 1126 to 1000.

If we suppose the Blood Globules to make $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$, or $\frac{1}{3}$ of the whole bulk, their Specifick Gravity will be respectively 1174, 1150, 1102, or 1078. So that upon any of these Suppositions, the Specifick Gravity of the Blood Globules will be considerably greater than that of the *Serum*, and consequently they cannot be suppos'd to be Vesicles fill'd with an Aereal Substance.

It will therefore perhaps be askt, What do they really consist of?

In order to come to a Solution of this Question, it may be proper to take notice,

That Blood is compos'd of Phlegm, Oil, Volatile and fixt Salts, and Earth. For as to the Spirit, we look upon it with Mr. Boyle, to consist of the Phlegm and Volatile Salt united together.

That the *Serum*, upon a Chymical Analysis, exhibits a great deal of the first of these, and the others in a very small quantity.

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That on the contrary the *Crassamentum* yields much less Phlegm, but the other Principles much more copiously than the *Serum*.

From which *Data*, I think, we may safely conclude, that the *Crassamentum*, or Globular part of the Blood, consists of some Phlegm united with the Oil and Salts, and a small quantity of Earth.

But what is the exact proportion of these several Principles to one another; what alterations are produced in the Body by a change of this proportion; how, and in what part these Globules are form'd; by what means they preserve their Figure, without dissolving in the *Serum*, or uniting with one another; what variations are made in their Specifick Gravities by Heat and Cold; and what are the effects of those Variations, are Questions not very easy to be solv'd, and yet of so much importance to the Animal Oeconomy, that it were greatly to be wisht, we had a number of *Data* sufficient to determine them.

P. S. Since this Paper was sent to the Press, I made the following Experiments, which serving to confirm the Method last made use of, for finding the Specifick Gravity of the Blood Globules, it may not be improper to relate them.

August 6. 1719. I took a lump of the *Crassamentum*, and wash'd it gently in fair Water, to free it from the loose Globules, which precipitating out of the *Serum*, after the *Coagulum* is form'd, do not unite into one Body with it. This done, I laid it on a spongy brown Paper, in order to drain off the superfluous Moisture. After which, weighing it first in Air, and then in Water, I found its Specifick Gravity to be $1083\frac{1}{2}$.

Another lump of the same *Craffamentum* being weigh'd in the same manner, its Specifick Gravity was 1082.9.

Sept. 18. 1719. I found the Specifick Gravity of another piece of *Craffamentum* to be 1082.1.

A second piece from the Blood of a different Person gave me 1086.1.

A third from the same Person gave 1086.6.

From this it follows that the Specifick Gravity of the Blood Globules is at least 1084, which is the *Medium* between these five Experiments.

But if we allow one half of the bulk of the *Craffamentum* to consist of *Serum*, filling up the Spaces between the Blood Globules, we shall find their Specifick Gravity to be 1138.

From this we must make a small abatement, because some part of the *Serum* must have been squee'd out from between the Globules, by their yielding to one anothers Pressure, when the lump of *Craffamentum* lay upon the Paper: and this will reduce their Specifick Gravity sufficiently near to 1126, as we had before determin'd it.

IV. *An Account of the Sunk Island in Humber, some Years since recover'd from the Sea. Being an Extract of a Letter Communicated to the Royal Society by John Chamberlayne, Esq;*
R. S. S.

THIS Island goes by the name of the *Sunk Island*, so called I suppose from the sinking Marsh Ground about it. As for its Original one may make pretty sure Conjectures of that I believe, because 'tis yet with-
in